THE UNIVERSITY OF ALBERTA

EFFECT OF ENERGY AND DIETHYLSTILBESTROL ON YOUNG BULLS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Effect of Energy and Diethylstilbestrol on Young Bulls" submitted by Ralph Victor Stredwick, B. S. A., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The present research project was designed with two levels of feeding to investigate the influence of diethylstilbestrol (DES) on the performance of bulls in a feedlot. Thirty hybrid bull calves with an average initial liveweight of 270±4.7 kg (mean and standard deviation) were used in this study. The project was also used to compare two methods (chemical analysis and specific gravity) for determining the body composition. The body composition was used to estimate the net energy for maintenance (NE_m) and gain (NE_g) for the ration.

An initial slaughter group of six bulls were slaughtered at the start of the experiment. Eight bulls were slaughtered after 56 days on test and the remaining sixteen bulls were slaughtered after 140 days on test. The different slaughter dates provided a wide range in age and body composition for evaluating the effects of DES on young bulls.

It was indicated that a significant linear relationship occurred between the chemical analysis of the carcass and specific gravity method for determination of whole empty body composition. These relationships are as follows:

$Y = 10.16 + 0.80\ x$ $\quad S_{y.x} = 1.14$

$Y = -0.57 + 1.08\ x$ $\quad S_{y.x} = 1.51$

$Y = -50.41 + 3.64\ x$ $\quad S_{y.x} = 0.65$

for water, fat and protein respectively. In the above equations x equals specific gravity results and Y equals

chemically determined results.

The effect of DES on young bulls on two levels of feeding (full and restricted) for 56 and 140 days was non-significant ($P>0.05$) for rate of gain, feed efficiency and body composition. Body composition included the percent fat, water and protein.

The NE_m and NE_g were calculated for the ration to be 1.218 Mcal per kg of dry matter intake and 1.122 Mcal per kg of dry matter intake respectively. The NE_{m+g} was calculated for the two levels of feeding to be 1.129 Mcal per kg of dry matter intake for full fed bulls and 1.131 Mcal per kg of dry matter intake for restricted fed bulls.

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INTRODUCTION

In today's world of beef production more emphasis is being placed on greater outputs of lean meat in shorter periods of time. It seems obvious from the large amount of information available that bulls have a faster rate of gain, on less feed, with a higher lean to fat ratio than other types of beef animals. It may even be possible to get better performance from these bulls by the use of feed additives such as (DES). The procedure of leaving males intact would also be beneficial to breeders, as they could select young sires after they had a longer period to demonstrate their growth potential.

A quick and accurate method to estimate body composition would be very desirable. The specific gravity of the carcass is one method being investigated to make body composition estimates. The knowledge of body composition makes it possible to determine carcass quality and animal value. Body composition also enable calculations of body energy gain which enables the calculation of energy values for the ration used.

The object of the present experiment was to evaluate the effect of DES on young feedlot bulls. Chemical analyses for water, fat and protein of the whole carcass were compared to predicted estimates for the same components of the whole empty body from carcass density measurements. Digestibility trials were run during this experiment. Energy values were determined for carcass components. The information from

digestion trials and energy determinations were used to establish a net energy of maintenance value and a net energy of gain value.

REVIEW OF LITERATURE

I. Historical Aspect

During the past one hundred and fifty years many systems of energy evaluation of feeds have been proposed. The Total Digestible Nutrients (TDN) system is the one most widely used. In 1963 Lofgreen introducted a system for expressing net energy values for growing and finishing feedlot cattle (Lofgreen, 1963 a, b, c). Lofgreen and Garrett, (1968) introduced a more complete form in 1968 which separated the requirements for animals into two groups; net energy for production (NE_p) and net energy for maintenance (NE_m). The National Research Council included NE_p and NE_m values in its 1970 bulletin (NAS-NRC 1970) on beef cattle requirements. However, the use of the net energy (NE) system is still in an experimental state.

The desire for a system other than TDN values has been expressed before (Maynard and Loosli, 1969; Crampton, Lloyd and MacKay, 1957; Garrett, Meyer and Lofgreen, 1959). Flatt, (1965) reviewed other workers practical feeding experiments with dairy cattle on the relative merits of TDN and estimated net energy. The general conclusion reached were that the TDN system overestimates the value of forages. Therefore, the estimated net energy system is more suitable for comparing values of forages and concentrates.

Flatt, (1965) made a very detailed comparison of TDN with other energy units. This review illustrated how complex

and varied the number of different energy systems are for evaluating feeds. Some examples of these different systems illustrated by Flatt, (1965) are shown below:

1 lb. TDN = 0.454 kg TDN

= 2000 kcal digestible energy (DE)

= 943 kcal net energy (NE assuming 57.5% efficiency of utilization of metabolizable energy)

Starch equivalents (SE) = 2356 kcal net energy for fatteing $(NE_f)kg_{SE}$

Scandinavian feed units (SFU)

= 1650 kcal NE/kg (for the average range of protein in feeds)

II. Development of the Net Energy System

The use of liveweight gain as an estimate of feed values can be misleading because cattle have different amounts of stomach fill. Therefore, it would be more accurate to relate estimates of feed values to carcass composition and gain. Carcass weight is easy to obtain and corrections can be made for both digestive tract fill and offal. Carcass weight should, therefore, receive primary attention in the analysis of results.

Lofgreen (1965) illustrated how NE values were used in the following series of equations.

The total net energy of a feed is commonly expressed as:

$$NE = ME - HI \quad (1)$$

where ME is metabolizable energy and HI is heat increment.

Total net energy of a given feed intake can also be expressed as:

$$NE = M + P \qquad (2)$$

where M is the energy expended for maintenance and P is the energy in any net increase in products such as new body tissue, milk, etc. The energy expended for maintenance is equal to the basal heat production (B) plus the heat of activity (A) thus:

$$M = B + A \qquad (3)$$

Equation 1 and 2 are equal and thus at a given feed intake

$$M + P = ME - HI \qquad (4)$$

By substituting for M equation 4 becomes

$$B + A + P = ME - HI$$

It is obvious, therefore, that

$$B + A + HI = ME - P$$

or

$$H = ME - P \qquad (5)$$

where H is total heat production and is equal to the sum of basal heat, heat due to activity and heat increment.

The net energy of production can be determined by a comparative slaughter method which is discussed in the next section of this thesis. The metabolizable energy can be determined from an energy balance trial. The heat production can be determined by using net energy of production and metabolizable energy of the ration.

Lofgreen and Garrett, (1968) illustrated a relationship between the daily heat production (HP) and metabolizable

energy intake over a range from maintenance to *ad libitum* feed consumption. They used a logarithmic equation to extrapolate to the heat production at zero energy intake which is the fasting heat production.

The equation used was:

$$\text{Log HP} = 1.8851 + 0.00166\ \text{ME}$$

where HP and ME are in kcal per $W^{0.75}$ kg. The log of the heat production of a fasting animal was reported to be 1.8851±0.0293. The antilog for the limits were 72 and 82 with a mean value equal to 77 kcal. The average NE_m requirements for cattle was, therefore, given as 77 kcal times $W^{0.75}$ kg. This value is used in the National Research Council's recommendation for calculating NE_m for beef cattle (NAS-NRC 1970).

It was illustrated by Lofgreen, (1965) that the net energy content of a ration for production plus maintenance was 1.44 Mcal per kg of feed at no production, 1.30 Mcal per kg of feed at a low rate of production and 1.06 Mcal per kg of feed when animals were fed *ad libitum*. The NE_p is much less than the NE_m per kg of feed for beef animals. The total net energy for maintenance and gain will approach the value of NE_p as the rate of production increases, but will never equal NE_p, since maintenance is always a part of the total.

III. Comparative Slaughter Method

A relationship between carcass specific gravity and percent separable fat of beef animals was first determined by Kraybill, Bitter and Hankins, (1952). This information, along with the relationships among major chemical components of the bovine, established by Reid, Wellington and Dunn, (1955), were used to develop a comparative slaughter method in which carcass specific gravity was used to estimate body composition (Garrett et al., 1959; Lofgreen and Otagaki, 1960; Meyer, Lofgreen and Garrett, 1960). This specific gravity technique is used to determine the composition of gain of a group of animals. The difference in whole empty body weight between a slaughter group at the start of the experiment, and the slaughtered animals at the end of the experiment, shows the whole empty body gain during the experiment. Then, by establishing an energy value for fat and organic matter not fat, one can determine the energy retained in the gain. The energy value for protein is that of the organic matter of the carcass with the fat removed.

Garrett and Hinman, (1969) determined the whole empty body weight of the animal by adding the warm carcass weight and the total weight of all non-carcass (ingesta-free) items. By ingesta-free, Garrett and Hinman, (1969) state that all material from the digestive tract is removed and the weight of the offal is included in empty body weight. The equation for calculating whole empty body weight from warm carcass

weight was revised by Garrett and Hinman, (1969). The revised equation is:

$$Y = 1.36\ x + 30.26 \qquad (6)$$

where x is the warm carcass weight.

The equation of Garrett and Hinman, (1969) has a smaller slope (1.36 vs. 1.45) than the one developed by Lofgreen, Hull and Otagaki, (1962) which only corrects for rumen fill and not the contents of the complete digestive tract. The equation for empty body weight by Lofgreen, et al. (1962) was:

$$Y = 1.45\ x + 31.8 \qquad (7)$$

where x is the warm carcass weight.

Both equations express the whole empty body weight in terms of kg.

Kraybill et al., (1952) have stated the body is comprised of a fat-free body mass of constant gross composition and a variable quantity of fat. If the fat-free portion of the body is constant in composition, it is to be expected that the density of this portion of the body must also be relatively constant. Kraybill et al., (1952) also states that fat, in relation to water, has a low density of 0.92, with that of muscle 1.06 and bone 1.50. These different densities are responsible for deviations in body specific gravity. The specific gravity of a carcass can be obtained by knowing the weight in air and the weight in water and using the following equation:

$$SG = \frac{\text{weight in air}}{\text{weight in air - weight in water}} \qquad (8)$$

Because fat has a lower density than water an increase in carcass fat will cause a decrease in carcass weight in water.

It was apparent to Kraybill et al., (1952) when they used a plot of specific gravity values for the dressed carcass against the specific gravity values of the whole animal (ingesta-free) that the composition of the dressed carcass is representative of that for the whole animal over a wide range of fatness. He thus derived the following relationship

$$Y = 0.9955\ x - 0.0013 \qquad (9)$$

where Y is the specific gravity of the whole empty body and x is the specific gravity of the carcass. These findings are in agreement with findings by Rathbun and Pace (1945) in their work on guinea pigs.

In the study of Kraybill et al., (1952) on 30 head of cattle, consisting of 15 steers and 15 heifers, the specific gravity ranged from 1.017 to 1.070 with a mean value of 1.045. The fat content varied from 39.5 to 13.6 percent of the body weight with an average of 25.1 percent. They found that there was a direct relationship between body water and body specific gravity. On the basis of the data for eviscerated cattle, a correlation coefficient of 0.984 was obtained for the relationship of water content and specific

gravity. The following equation can be used to determine body water

$$\% \text{ Body water} = 100[4.008 - 3.620/\text{sp gr}] \qquad (10)$$

Reid et al., (1955) found an inverse relationship between body fat content and water content of the bovine body. He derived equations for the prediction of the fat content from water content for dairy and beef cattle of mixed sexes. As a result of the studies by Kraybill et al., (1952) and Rathbun and Pace, (1945), it was assumed generally that the relationship between the percentages of fat and water were inverse but linear. Reid et al., (1955) found that curvilinear equations express the relationship between the percentages of water and fat more accurately than the corresponding linear equations. Reid et al., (1955) derived the following equation to estimate carcass fat content.

$$Y = 337.88 + 0.2406\ x - 188.91 \log x \qquad (11)$$

In this equation Y is the percent fat and x is the percent water content of the whole empty body.

Highly significant correlation coefficients were found between age of cattle and the protein content of the fat-free dry matter (Reid et al., 1955). The relationship between age and protein percent of the fat-free dry matter of the body was expressed as

$$P = 80.80 - 0.00078\ z \qquad (12)$$

where P is the percent protein of the fat-free dry matter and z is the age in days.

The next equation developed by Reid et al., (1955) was:

$$P_1 = \frac{P \text{ (percent fat-free dry matter)}}{100}$$

where P_1 is the percent protein of the whole empty body.

These equations will be used later in this thesis as a method for determining the composition of the gain.

IV. Diethylstilbestrol Effect on Composition of Gain

Beeson, (1969) reported that approximately 80% of the cattle in feedlots are either implanted with, or are fed, DES. Work has been done which showed increased rate of gain and feed efficiency in steers receiving DES (Dinnuson, Andrews and Beeson, 1950; Clegg and Carroll, 1956; and Clegg and Carroll, 1957). It has also been concluded that carcass fat is decreased in steers fed DES (Bailey, Probert and Bohman, 1966a). It is generally accepted that bulls produce more carcass lean than steers. However, the effect that DES supplementation has on the carcass composition of bulls is not yet fully understood.

Results from an experiment by Bailey et al., (1966a) as in other studies (Hedrick, Thompson and Krause, 1969; and Nygaard, Radloff and Riley, 1971), indicated that bulls not receiving DES gained more rapidly and required less feed than did steers. Bailey et al., (1966a) found that bulls treated with DES and fed *ad libitum* did not gain significantly more rapidly than untreated bulls fed *ad libitum*

and there was not a significant difference in the feed required per unit of gain.

In various experiments it has been shown that bulls have a lower percentage of ether extract in the longissimus dorsi muscle, lower marbling score and lower carcass grades than steers (Hedrick et al., 1969; Nygaard et al., 1971). The total weight and percent retail cuts, as well as area of longissimus dorsi muscle of the carcass of bulls, has been consistently greater than steers (Hedrick et al., 1969; Nygaard et al., 1971).

In two experiments conducted by Bailey et al., (1966 a,b) bulls treated with DES were somewhat fatter than untreated bulls and the carcass grades were slightly higher for treated bulls. Higher carcass grades are believed to be caused by increased carcass fat. The differences noted by Bailey et al. (1966 a, b) were not statistically significant, nor were results on the effects of DES on bulls reported by other workers (Cahill, Kankle and Klosterman, 1956).

The evidence indicates that bulls gain more rapidly and are more efficient than steers. At the levels of DES that have been used on bulls, it would appear that DES has only a very small effect.

EXPERIMENT AT THE UNIVERSITY OF ALBERTA

I. Objectives

The present research project with young bulls of hybrid breeding has been directed toward the following objectives:

(i) to study the performance of young bulls on full and restricted feed.

(ii) to study the effect of diethylstilbestrol on young bulls.

(iii) to compare whole empty body composition predicted from specific gravity to the carcass composition determined by laboratory analysis and

(iv) to accumulate data that may be used to estimate net energy requirements for young bulls.

II. Introduction

Most of the beef production for the fresh meat trade has been traditionally from steers and heifers. This is mainly because of the preferences of packers and retail buyers for steers and heifers. In recent years, it has become quite obvious that young bull carcasses have a higher proportion of lean meat. Therefore, more people have been considering use of young bulls for beef production.

It is recognized that bulls exhibit better feedlot performance than steers and that steers are superior to heifers. The net energy required for gain, and that required for maintenance, are not well known for young bulls. One way to estimate the net energy required for gain by an animal is to measure the energy of the gain of that animal. Classically, the measure of energy retention has been done with respiration calorimeters. Also, indirect calorimetry has been used, in which the kind of tissue gained can be determined from carbon and nitrogen balance studies. A major disadvantage of respiration studies is that they consist of relatively short periods of measurement during which the animals are exposed to unnatural conditions. These studies are also limited by the number of animals that can be tested at any given time. Attempts have been made to overcome these disadvantages by using weight gains on large numbers of animals as measures of energy retention. Weight gains, as they relate to energy retention, have a

major disadvantage. It cannot be assumed that the caloric value of gain is the same for all animals. However, the composition of gain can be measured by a comparative slaughter technique. This technique utilizes carcass density to predict carcass water, fat and protein. The composition of the weight gain can be determined from a comparison of an initial slaughter group with animals slaughtered at the conclusion of the trial. By applying the appropriate energy values for fat and protein the energy gain can be determined.

A comparative slaughter experiment was set up at the University of Alberta Beef Cattle Research Station at Ellerslie with bulls fed at full and restricted levels of intake. Studies of growth rate and feed consumption were carried out over a 22 week period. Digestibility studies and carcass studies were done to delineate the energy of the carcass gain of each of the animals.

III. Materials and Methods

A. Description and Management of Experimental Animals

The experiment was conducted from January to June in 1971 (140 days) using 30 hybrid bulls from the University Ranch at Kinsella. Upon arrival, the bulls were individually weighed and given long hay, trace mineralized salt and water free-choice for the first three days. Immunization against bovine rhinotracheitis (IBR); blackleg; malignant edema; perfringes B, C, and D; *Clostridium novyi* and tetanus as well

as identification by ear tags had previously been done at the University Ranch. The bulls were given 2 ml injections containing 500,000 IU of vitamin A, 50,000 IU of vitamin D_3, and 50 IU of vitamin E per ml.

All bulls were given 2.7 kg of concentrate and long hay free-choice for a week. The bulls were then brought up to 50 parts concentrate and 50 parts chopped hay and held at this level for 30 days. All bulls were brought up to a ratio of 85 parts concentrate and 15 parts hay, one week prior to making final allotments.

The bulls were allotted into five groups including one initial slaughter group and four treatment groups. The initial slaughter group was made up of the three heaviest and the three lightest bulls. The four treatment groups were formed by randomly allotting the bulls into groups by weight, with a selected and similar range of weights from heavy to light in each group.

The four groups of bulls were placed on two levels of feeding with half the animals on each level receiving 20 mg per head per day of DES. The initial slaughter group received no DES. The same ration was used for all the treatment groups (Table 1).

The four groups were treated as follows:

Group I - full feeding plus DES

Group II - full feeding

Group III - restricted feeding plus DES

Group IV - restricted feeding

TABLE 1. - Ration formulation and composition

	Total ration	Concentrate ration	Hay
Ingredients %			
Chopped hay	15.0	-	-
Barley	70.5	83.0	-
Oats	10.0	11.8	-
Salt, trace mineralized	1.00	1.18	-
Limestone	0.75	0.88	-
Sodium, tripolyphosphate	0.23	0.26	-
Premix[1]	2.50	2.94	-
Composition, DM basis %			
Dry matter	88.2	88.2	88.4
Crude fiber	13.4	9.0	38.0
Crude protein	12.9	12.6	14.7
Calcium	0.45	0.26	1.51
Phosphorus	0.38	0.44	0.08
Crude fat	2.2	2.4	1.4
Ash	5.2	4.4	9.8
Nitrogen free extract	66.3	71.6	36.1

[1]The premix supplied the following: ground barley, 81.29%; sulfur, 1.7%; vitamin A, D and E, 1.7% (A 10,000 I.U./gm, D_3 1,000 I.U./gm, and E 100 I.U./gm) and Urea (282%) 15.31%.

The bulls on full feed received all the rations they would consume. The bulls on restricted feeding were allowed rations to equal National Research Council (NAS-NRC 1970) requirements for maintenance and growth of 0.5 kg per day.

Each group of bulls was kept in a single pen and bedded with wood shavings. The rations were fed twice daily to each pen of bulls at 0800 and 1530 hours. The bulls had free access to water and trace mineralized salt.

The bulls were weighed at the beginning of the experiment and every twenty-eight days for the first two periods, then every fourteen days for the remainder of the trial. The change in weighing to every fourteen days was done to keep a closer control on the bulls' weights in the restricted feeding groups. All weights were taken after twelve hours off feed and water.

After 56 days on feed, two animals per group were selected and slaughtered. These animals represented the average liveweight from their individual groups. At the end of the trial the remainder of the animals were slaughtered. One animal (Bull number 212 of Group II) was slaughtered on May 11, 1971 before the end of the trial because of an abcess on his tongue which caused reduced feed intake.

B. Metabolism Studies

Three metabolism studies were conducted during this experiment. The first two were done simultaneously from

April 21st to April 23rd. The third was done from May 17th to May 20th. The first metabolism trial was done using chromic oxide (Cr_2O_3) as an external indicator. The second and third entailed total collection of fecal matter.

During the metabolism studies with Cr_2O_3, the sixteen bulls remaining in the four treatment groups were fed Cr_2O_3 at a level of 0.475% of the ration for fourteen days. Fecal grab samples were then taken from each bull for three days at 0700 and 1400 hours, dried and stored for analyses. For the second and third metabolism studies one bull from each treatment group was fitted with a harness and collection bag (Figure 1) and different bulls were used for each trial. The apparatus used for total fecal collections was similar to that described by Hoogendoorn and Grieve (1969). These bulls were allowed to remain in their pens during the collection period. The bags were changed at 0700 and 1400 hours each day, at which time the amount collected was weighed and a sample equal to approximately 2% of the total weight of the feces was obtained.

Fecal samples were placed in aluminum pans and dried to constant weight in a forced air oven at 60°C. The residues were ground in a laboratory mill and composited to provide one dried fecal sample for each bull for each collection period. Feed samples were obtained during each trial, ground in a laboratory mill, and retained for analyses for dry matter, Cr_2O_3, gross energy and protein.

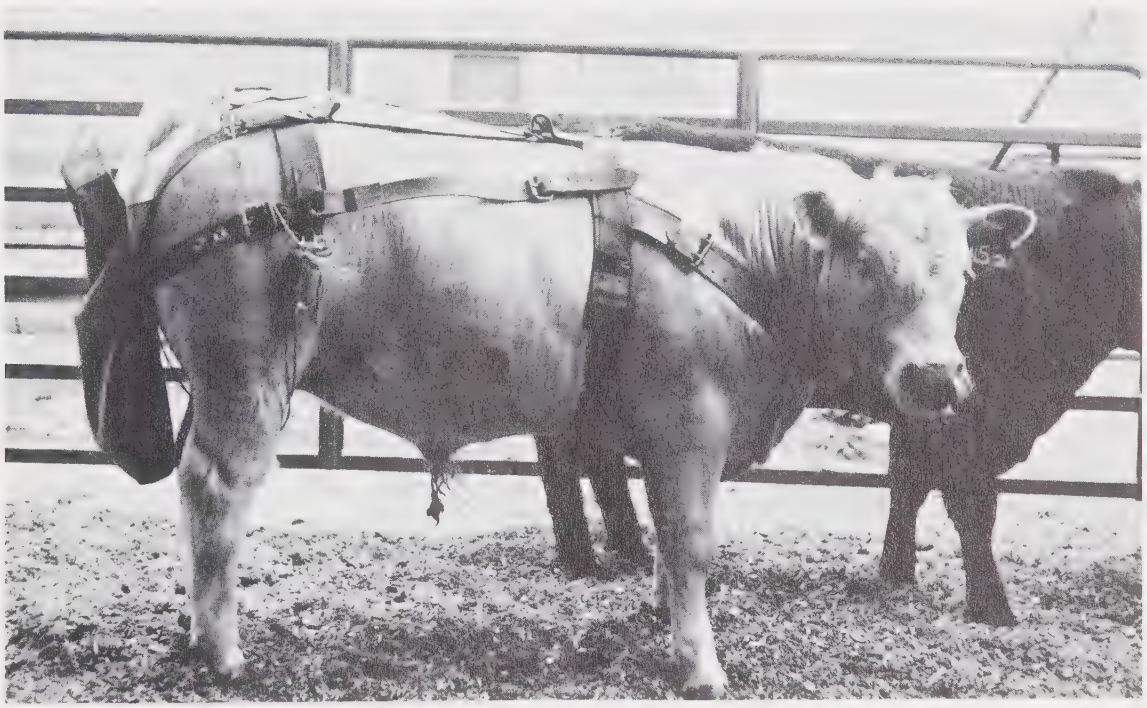

Figure 1. Fecal collection harness

C. Carcass Studies

The bulls were all slaughtered at a commercial slaughtering plant where the left side of each carcass was weighed in air to the nearest 0.5 pound and then weighed under water to the closest gram. The carcasses were graded by Government graders and Record of Performance (ROP) measurements were made. These measurements consisted of loin eye area, back fat thickness and a marbling score. The weight measurements were taken forty-eight hours after slaughter to obtain a uniform carcass temperature. The temperature of the water in the weighing tank was adjusted to the carcass temperature of approximately $4^{o}C$ with ice one day prior to use. The weighing tank was then left in the cold room with the carcasses until the hydrostatic weighing was done. This procedure enabled a precise measurement to be taken with a minimum of air pockets and provided similar water and carcass temperatures. Figure 2 illustrates the water tank used for specific gravity measurements.

The empty body weight of the slaughtered animals was estimated using the equation

$$Y = 30.26 + 1.36\ x$$

where x is the warm carcass weight (Garrett and Hinman 1969). The initial empty body weight was estimated from a ratio of the initial live shrunk weight to empty body weight of the initial slaughter group. This ratio is illustrated in the following equation:

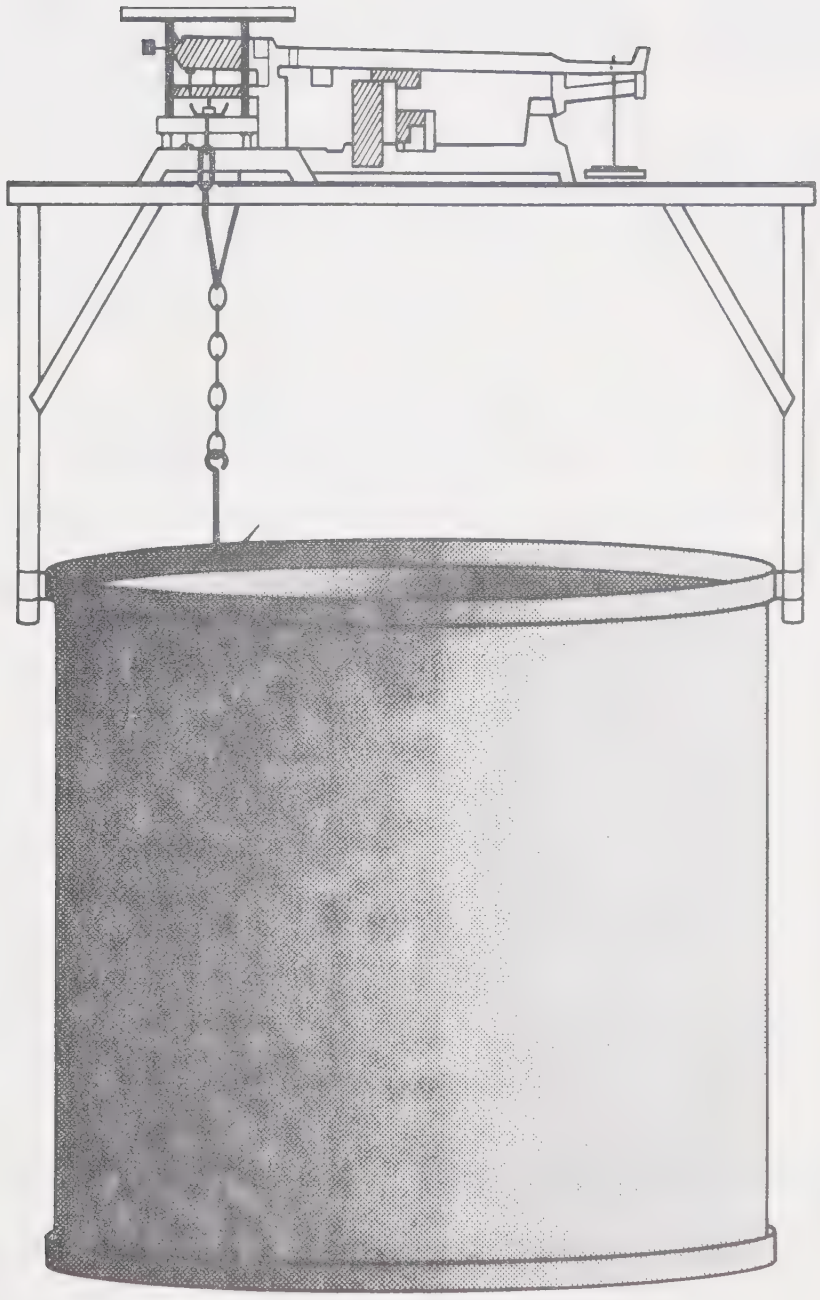

Figure 2. Water tank for specific gravity measurements

$$\frac{\text{Initial slaughter group empty body weight}}{\text{Initial slaughter group shrunk weight}} \times \text{Test group initial shrunk weight} = \text{Initial empty body weight of test group} \quad (1)$$

Carcass specific gravity is calculated from the left side weights in air and under water taken in the plant from the equation (Kraybill et al., 1952).

$$SG = \frac{\text{Weight in air}}{\text{Weight in air - Weight in water}} \quad (2)$$

The specific gravity of the whole empty body was predicted from the equation given by Kraybill et al., (1952) where x is the dressed carcass specific gravity.

$$Y = 0.9955\ x - 0.0013 \quad (3)$$

Empty body water is determined from the equation:

$$\text{Percent body water} = 100[4.008 - 3.62/Y] \quad (4)$$

where Y is the whole empty body specific gravity from equation 3 (Kraybill et al., 1952).

Body fat is calculated from body water by the equation for beef cattle:

$$\text{Percent body fat} = 337.88 + 0.2406x - 188.91 \log x \quad (5)$$

where x is percent body water (Reid et al., 1955).

Protein in the fat-free dry matter and in the empty body is determined from the equations for beef cattle:

$$P = 80.80 - 0.00078\ z \quad (6)$$

and

$$P_1 = \frac{P(\text{percent fat-free dry matter})}{100} \quad (7)$$

where P is the protein in fat-free dry matter, z is age in

days. The fat-free dry matter is 100 minus percent fat and percent water. P_1 is the percent protein of the whole empty body (Reid et al., 1955).

The left side of 22 carcasses were returned to the University Meat Laboratory for physical dissection into muscle, fat, tendon and bone. The halves of carcasses which were returned were as follows: six from the initial slaughter group, eight slaughtered at 56 days and eight of the remaining sixteen at 140-days.

From each of these dissected carcasses, six samples of muscle, three samples of fat, all the tendons and three samples of bone were taken from each animal. The dissected muscles and fat were each ground separately and thoroughly mixed before sampling for analyses. The bones were put in three groups, ground and one sample taken from each group. The groups were as follows:

Group 1: ribs, sternum and rib cartilage

Group 2: thoracic vertebrae, cervical vertebrae and atlas

Group 3: pelvis, femur, patella, tibia, tuber calcis, scapula, humerus, ulna, radius and the carpus

The samples were frozen and stored for later analyses for protein, fat, dry matter and ash.

D. Analytical Methods

Dry matter was determined on feed and fecal samples by using the Association of Official Agricultural Chemists (1965) method. Nitrogen was determined by Macro-Kjeldahl

analysis and converted to protein by using a factor of 6.25. Gross energy of feed and fecal samples were determined by combustion in a Parr oxygen bomb calorimeter. Ash was determined in a muffle furnace for four hours at 600^{o}C; while ether extraction was carried out in the Goldfisch apparatus.

The crude fibre on feed and fecal samples was determined by the acid detergent method of Van Soest (1963). The Cr_2O_3 determination was done spectrophotometrically by the Hill and Anderson (1958) method with two alterations. In step four the flasks were air cooled rather than chilled in ice water. In the next step the flasks were diluted with 60-ml of distilled water and 20-ml of concentrated H_2SO_4 rather than 90-ml of distilled water before being made up to 110-ml volume.

The nitrogen free extract was estimated for feed and fecal samples by difference on a dry matter basis.

Chemical analyses for protein, fat and water were done on the samples of the dissected muscle, fat, tendon and bone. The proportion of muscle, fat, tendon and bone consisting of protein, fat and water were determined by using the chemical results. The total protein for the carcass was the sum of the protein from the muscle, fat, tendon and bone. Total fat and total water were calculated in the same manner as protein. The total weight of each component was divided by the total carcass weight and the percent of each component of the carcass was determined by multiplying by 100.

Dry matter was determined on carcass samples with a freeze drier. Samples were dried for three days in a freeze drier under vacuum and at -55°C. The meat and tendon samples were dried for an additional two hours at 110°C to determine dry matter. Dry matter for fat was determined from freeze dried samples. Bones from the complete left side were cut into two inch pieces and dried in an oven at 60°C for three days, after which the bone samples were dried at 110°C for an additional two hours to determine the moisture level.

It should be pointed out here that the protein in tendon is slightly over estimated by the factor 6.25 because it is composed predominantly of collagen with a nitrogen content of 18.6% (Bear 1952), thus a more correct factor for tendon would be 5.56. A significant error in total calculation would not be caused by using the factor 6.25 for tendons, because the tendons only represent a small fraction (1.28%) of the total carcass weight. Protein was determined on the residue of hexane extracted fat samples by using Macro-Kjeldahl analysis. All fat samples were extracted with hexane by mixing the sample with hexane in a blender. The sample was then placed in a column and flushed with hexane until a dry residue was formed. The residue was removed from the column and oven dried at 110°C for two hours to determine the complete dry matter for protein analysis.

Gross energy was determined on the non-fat organic matter, and the lipid of the carcass, by combustion in a Parr oxygen bomb calorimeter. The fat extracted muscle samples were used for the non-fat organic matter and pure lipid samples were obtained from fat samples by ether extraction.

E. Statistical Analysis

The regressions, correlations and analysis of variance were calculated according to methods described by Steel and Torrie (1960). Regressions were tested for significance by a T-test and the F-test was used for analysis of variance (Steel and Torrie, 1960). The MTS operating system of the University IBM 360/67 computer was used to do all statistical calculations.

IV. Results and Discussion

A. Comparison of Methods for Carcass Evaluation

Comparisons were done between chemically determined water, fat and protein of bull carcasses and the same components calculated from the specific gravity measurements of the whole empty body (whole body weight minus gut content). Specific gravity measurements were used to estimate the percent water, fat and protein by using equations 3 to 7 of the experimental section of this thesis. Equation 1 from the experimental section was used to estimate whole empty body weight from warm carcass weight. A complete physical dissection of the left side of the carcass was done to separate the carcass into muscle, fat, tendon and bone. Samples from the muscle, fat, tendon and bone were obtained and chemically analyzed for protein, fat and water.

The percent water in the whole empty body estimated from the specific gravity of the chilled carcass and the percent of water in the carcass determined by chemical analysis as shown in Table 2, were 62.97% and 60.43%, respectively. The difference between the two methods of 2.54% was significant ($P<0.01$). The difference is accounted for by evaporation losses during the handling of the carcass for dissection. The average loss of weight from slaughter to complete dissection of the carcass was 1.8 kg or 3.05%. The loss of moisture due to evaporation and "oozing" was one of the most critical points of error as explained by Mukhoty (1969) during dissection of bovine carcasses. In Figure 3 the regression equation is

TABLE 2. - Means, standard deviations and range of values for methods of carcass analyses

Item		Mean	Standard deviations	Range
Water	Lab. (%)[1]	60.43	2.14	56.72-64.19
	Sp. Gr. (%)[2]	62.97	2.30	59.84-68.15
Protein	Lab. (%)	19.34	0.74	18.01-20.71
	Sp. Gr. (%)	19.19	0.10	18.99-19.30
Fat	Lab. (%)	13.65	2.97	7.84-19.29
	Sp. Gr. (%)	13.21	2.39	7.92-16.59

[1] Percent of chilled carcass determined from chemical analyses.

[2] Percent of whole empty body calculated from specific gravity.

plotted for the predicted percent water which is made up of values from specific gravity measurements and plotted against the measured percent water values from the chemical analysis. The regression equation for this relationship is $Y = 10.16 + 0.80 x$ where x equals the percent water predicted from specific gravity measurements with a standard error of the estimate of ±1.14. The significant ($P<0.01$) Student's T-test shows it is valid to consider the specific gravity predicted water values as good predictors of chemically determined values. The correlation coefficient of 0.86 indicates that there is a good linear relationship between the two methods for measuring carcass water content.

It has been illustrated by Garrett and Hinman (1969) that the specific gravity is a good estimate of whole empty body water composition with a correlation coefficient of 0.93 between specific gravity and whole empty body water. However their estimate was based on data from chemical measurements of carcass components and of empty body components which did not involve comparisons between chemical analysis and specific gravity estimates. The high correlation shown in the work of Garrett and Hinman (1969) of 0.99 for water should be expected between carcass components and the same components for the whole empty body.

The analysis of variance of the specific gravity results and laboratory results for the degree of fat in the carcass showed no significant difference ($P>0.05$). The

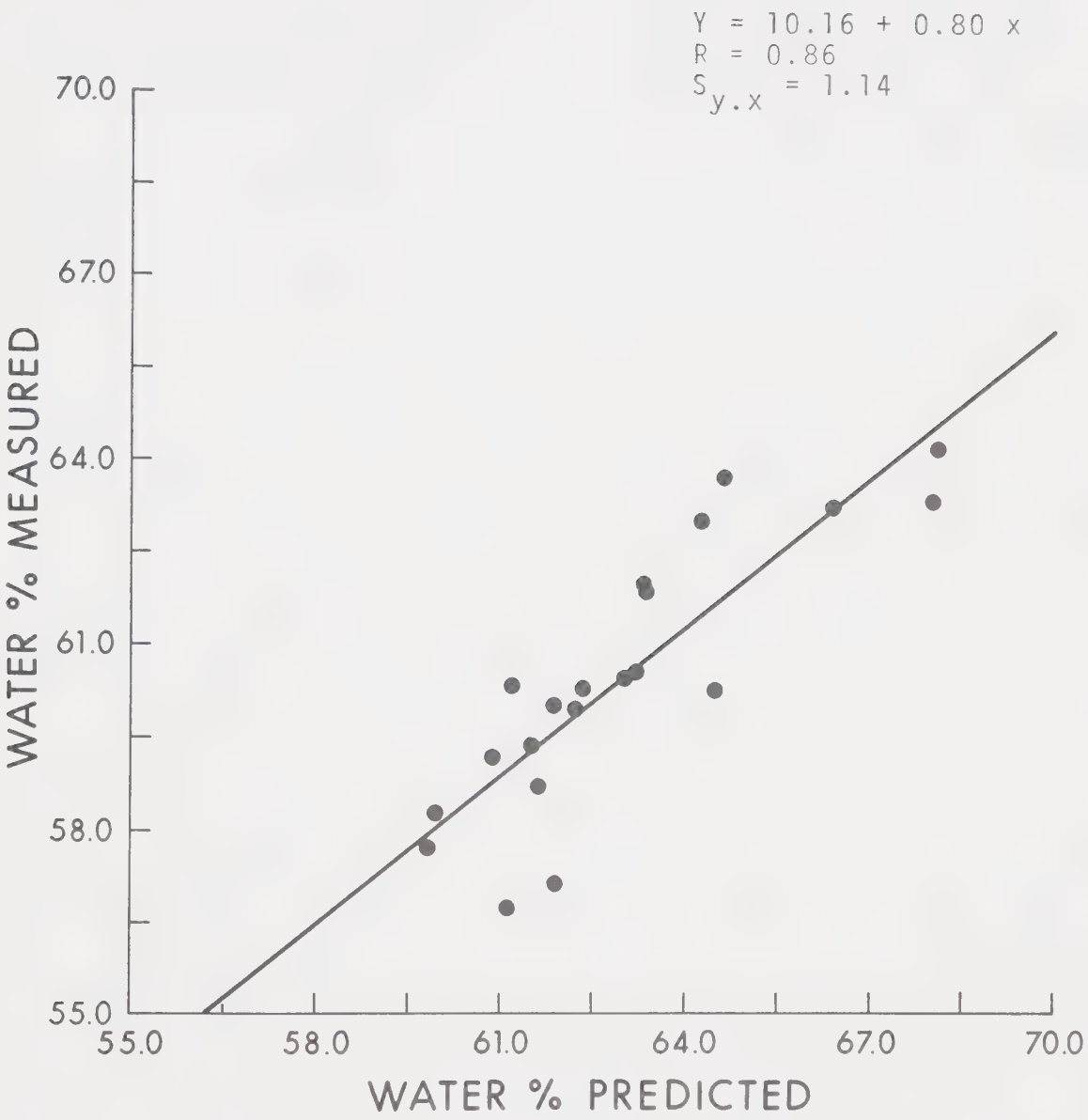

Figure 3. The relationship of the predicted and measured water (predicted values are calculated for whole empty body from specific gravity measurements; measured values are determined from chemical analysis of the carcass).

relationship between the two methods is illustrated by the regression equation $Y = -0.57 + 1.08\ x$, where x equals percent fat predicted from specific gravity measurements, with a standard error of estimate of ±1.51 as shown in Figure 4. The Student's T-test shows a significant ($P<0.01$) relationship for the regression which shows it is valid to consider the specific gravity predicted values for fat as good predictors of chemically determined values. The relationship between the two methods shows a positive correlation coefficient of 0.87 indicating a good linear relationship.

The regression developed by Garrett and Hinman (1969) between the percent fat of the whole empty body and specific gravity showed a very negative relationship. His data showed a correlation of -0.96 with a standard error of estimate of ±1.59 for percent fat and specific gravity.

The comparison in this experiment of the two methods for evaluation of carcass protein by analysis of variance was not significant ($P>0.05$). The correlation coefficient of 0.49 for the two methods was lower than in the case of water and fat. The regression equation $Y = -50.41 + 3.64\ x$, where x equals the percent protein predicted from specific gravity measurements with a standard error of estimate of ±0.65 as shown in Figure 5 was significant ($P<0.05$). The significance of this regression makes it valid to consider specific gravity values for protein as good predictors for those determined chemically. Estimated protein values of 16.70

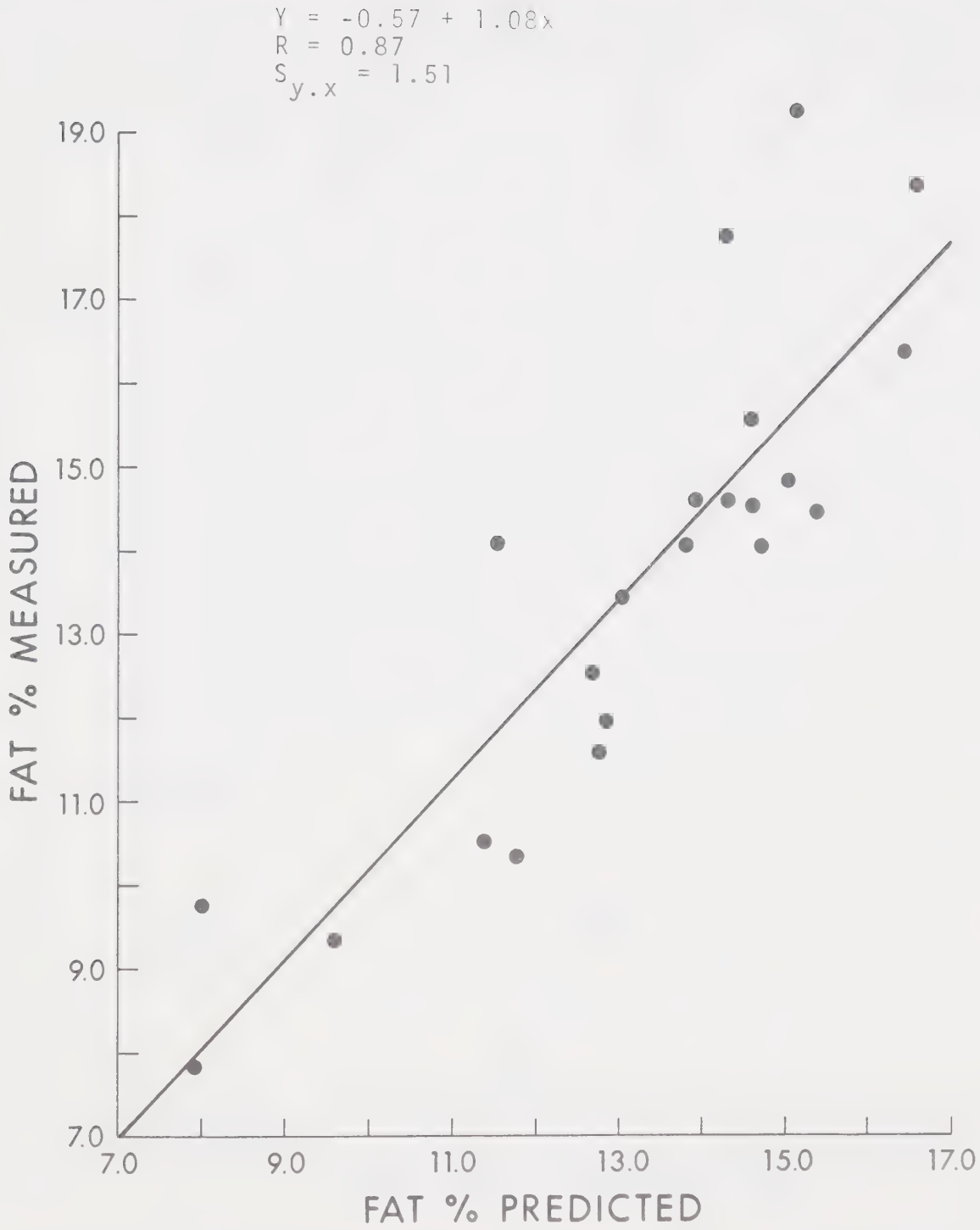

Figure 4. The relationship of predicted and measured fat (predicted and measured percentages are as in Figure 3).

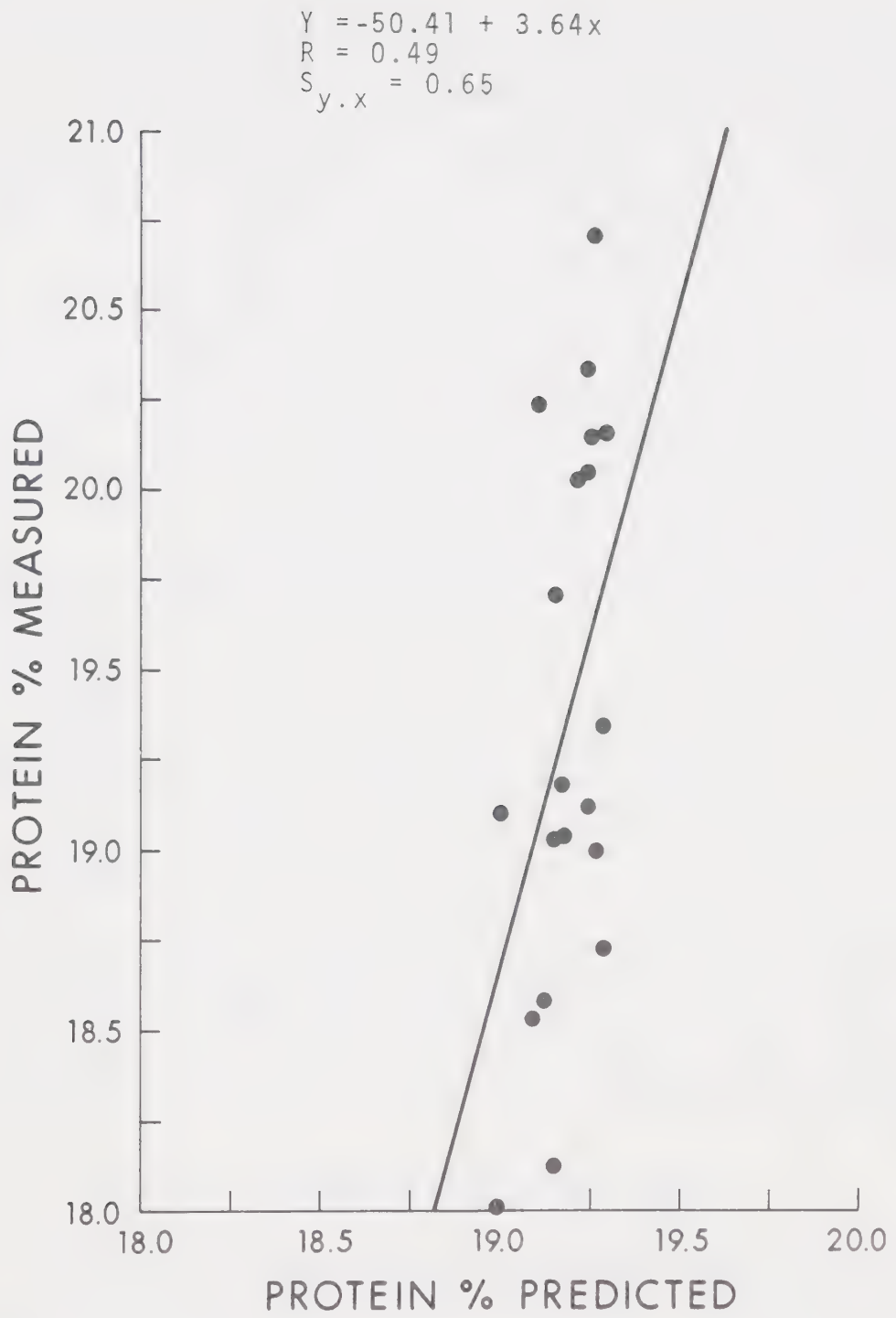

Figure 5. The relationship of predicted and measured protein (predicted and measured percentages are as in Figure 3).

to 19.3 percent were calculated and plotted against specific gravity values of 1.0300 to 1.0950 in Figure 6, to help explain the low precision between predicted and measured protein values. These calculations revealed that protein values determined from specific gravity measurements will remain quite linear and then plateau at approximately 19.2% protein as shown in Figure 6. The protein values predicted from specific gravity for the bull carcasses were in the range of 18.99 to 19.30 with a mean of 19.19%. Both predicted and chemically determined protein values had a very narrow range around an overall mean for both of 19.26%. Therefore, large animal variations in chemical results made it difficult to develop a good fit to the regression equation.

A narrow range or constant value for carcass protein with variable carcass fat and water was also reported by Reid et al., (1955). They reported that the percentages of fat and water in the whole empty body are variable while the percentages of protein and ash are practically constant.

B. Effect of Diethylstilbestrol on Bulls

The bulls in this experiment were treated with DES to determine the effect of DES on bulls under feedlot conditions. One-half of the bulls on full feeding and one-half of the bulls on restricted feeding received the DES treatment.

The performance data for the 56-and 140-day feeding

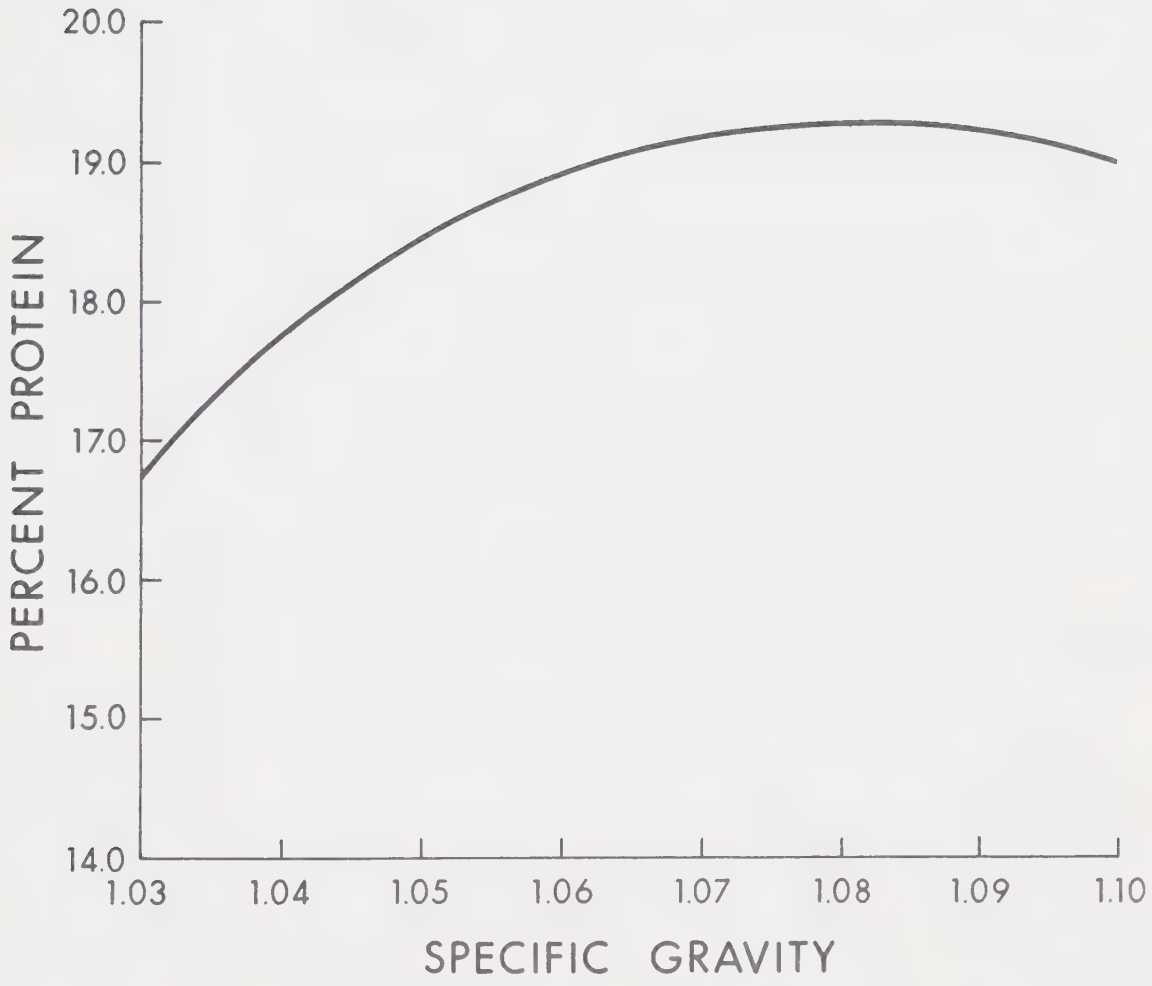

Figure 6. Relationship of specific gravity to protein level for 400 days of age.

periods are summarized in Table 3. When the bulls treated with DES were compared with untreated bulls for rate of gain there was no significant difference ($P>0.05$). However, the bulls that were on full feed plus DES had 11.6% and 13.6% higher rates of gain after 56-and 140-days on feed, respectively, compared to the bulls on full feed without DES. Diethylstilbestrol had very little effect on the performance of bulls that were on restricted feeding. Bulls on full feed with and without DES showed a reduction in average rate of gain after 140-days on feed compared to 56-days on feed. The restricted bulls showed very little change in rate of gain over time. Live weight gain showed non-significant ($P>0.05$) results for DES treated and untreated bulls for both levels of feeding and for both feeding periods.

Previous work reported by Clegg and Carroll (1957) and Bailey et al. (1966a) illustrates similar results to this study for the effect of DES on rate of live weights gain in young bulls. Cahill et al. (1956) indicated that there were no significant differences in bulls caused by the use of DES. Bailey et al. (1966a) showed DES treated bulls only gained slightly more rapidly than untreated bulls and that there was no significant difference in their rate of gain or feed required per unit of weight gain.

The feed efficiency was not affected by DES in this experiment. This is illustrated by the same value of 7.6 kg of feed per kg of gain for DES treated and untreated bulls

TABLE 3. - Average daily feed consumption, rate of gain and feed efficiency

	1 DES Full feed	2 Full feed	3 DES Restricted feed	4 Restricted feed
56-day period				
Average initial weight - kg	270	270	270	270
Average final weight - kg	351	342	306	308
Average daily gain - kg	1.44	1.29	0.64	0.67
Average daily feed intake - kg	8.6	7.7	5.3	5.3
Feed/kg gain - kg	6.0	6.0	8.2	8.0
140-day period				
Average initial weight - kg	270	270	270	270
Average final weight - kg	436	424	363	360
Average daily gain - kg	1.17	1.03	0.66	0.64
Average daily feed intake - kg	8.9	7.8	5.4	5.4
Feed/kg gain - kg	7.6	7.6	8.2	8.5

on full feed for 140 days. Similar, non-significant ($P>0.05$) results for 56 days on full feed and for the restricted feeding groups were also found (Table 3).

The effect of DES on the carcass composition of young bulls is summarized in Table 4. The results indicated that DES had no significant ($P>0.05$) effect on the percent, or weight, of the carcass water, fat or protein. A comparison of carcass fat levels for the full fed bulls showed average values of 16.06% and 13.37% for those receiving DES and the untreated bulls, respectively. This slight degree of fatness may have resulted in better grades (Table 5) for DES treated bulls at 140 days compared to the untreated bulls. The Record of Performance (ROP) data for the bull carcasses is given in Table 5 along with the grades and dressing percentages. There was no differences in dressing percentage, backfat, loin eye area and marbling score as a result of feeding DES to young bulls. This data agrees with results published by Bailey et al. (1966b) and Cahill et al. (1956), who found a trend that was not statistically significant towards an increased level of carcass fat due to DES supplementation.

Because of a lack of any difference caused by DES in this experiment the results were analyzed in two main groups (full and restricted feeding). This yielded larger numbers of observations in the groups for statistical analysis in determining the net energy of the ration.

TABLE 4. - Carcass characteristics of slaughter groups based on specific gravity

		Initial slaughter group	56-day period				140-day period			
			Group 1 DES Full feed	Group 2 Full feed	Group 3 DES Restricted feed	Group 4 Restricted feed	Group 1 DES Full feed	Group 2 Full feed	Group 3 DES Restricted feed	Group 4 Restricted feed
No. of bulls		6	2	2	2	2	4	3	4	4
Final empty body weight	- kg[1]	-	319.6	306.0	267.8	273.6	397.6	393.6	313.1	313.1
Initial empty body weight	- kg	253.3	256.6	256.6	256.2	256.6	256.6	256.6	256.2	256.6
Empty body water	- %	61.79	62.28	61.62	61.12	63.44	60.32	62.77	66.53	66.31
Empty body fat	- %	14.43	13.91	14.69	14.12	12.67	16.06	13.37	10.57	9.73
Empty body protein	- %	19.16	19.18	19.12	19.14	19.24	19.00	19.20	19.28	19.28
Empty body weight gain	- kg	-	62.06	49.40	11.61	17.01	141.02	137.03	56.97	56.52
Empty body weight gain water	- kg	-	39.21	30.44	7.10	10.79	85.06	86.02	37.90	37.48
Empty body weight gain fat	- kg	-	8.76	7.26	1.64	2.15	22.65	18.32	6.02	5.50
Empty body weight gain protein	- kg	-	12.07	9.44	2.22	3.27	26.79	26.31	10.99	10.90

[1]Empty body weight represents the ingesta-free body weight.

TABLE 5. - R.O.P. carcass characteristics

		56-day period				140-day period			
	Initial slaughter group	Group 1 DES Full feed	Group 2 Full feed	Group 3 DES Restricted feed	Group 4 Restricted feed	Group 1 DES Full feed	Group 2 Full feed	Group 3 DES Restricted feed	Group 4 Restricted feed
No. of bulls	6	2	2	2	2	4	4	4	4
No. grading									
Canada choice	-	-	-	-	-	1	-	-	-
Canada good	-	-	-	-	-	2	-	-	-
Canada standard	4	2	1	2	1	1	4	1	-
Canada commercial	2	-	-	-	-	-	-	-	-
Canada utility	-	-	-	-	1	-	-	1	4
Canada manufacturing	-	-	-	-	-	-	-	2	-
Average dressing percentage - % (warm carcass - station weight)	57.6	60.8	57.9	55.8	56.4	60.2	60.0	58.1	57.9
Average loin eye area, in	7.67	11.12	9.38	8.5	9.0	11.75	11.75	10.81	9.81
Average back fat, in	0.11	0.25	0.32	0.22	0.18	0.43	0.28	0.08	0.75
Average marbling score[1]	8.8	9	8.5	9	8.5	7.25	7.75	8.75	9

[1]Subjective trait for marbling is coded as 6=modest, 7=small, 8=slight, 9=none.

C. Energy Evaluation of the Ration

An objective of this experiment was to estimate the net energy of maintenance (NE_m) and the net energy of gain (NE_g) for the ration. To be able to determine the net energy values of a ration the following factors must be known: gross energy of the ration; digestibility of the ration; the metabolizable energy of the ration; the total empty body weight gain; and the gross energy of the empty body weight gain.

The average gross energy value of the ration used in this experiment was 4.430 kcal per gm on a dry matter basis.

The digestibility of this ration was estimated by total collection of fecal matter and by use of Cr_2O_3 as an external indicator. The results of the collection trial and the Cr_2O_3 trial are shown in Table 6. Fecal samples for total collections were taken from two bulls at separate times (April and May) for each treatment. The variability in this data between the two collection dates and among the groups was too large to be accepted and therefore the Cr_2O_3 or external indicator method which involved all 16 bulls on test was used. It is considered that some of the variability in the total collection trial was caused by using average feed consumption of the group for calculation of digestibility from individual collections. The animals used for the total

TABLE 6. - Apparent digestion coefficients

	Full feeding		Restricted feeding	
	Group 1 DES	Group 2 control	Group 3 DES	Group 4 control
Total collection (1)				
Dry matter - %	87.9	87.5	79.4	51.8
Energy - %	87.2	87.0	78.6	49.6
Protein - %	87.9	88.5	84.4	58.4
Total collection (2)				
Dry matter - %	73.4	50.3	43.7	81.6
Energy - %	71.4	47.6	41.2	80.9
Protein - %	65.6	47.6	45.4	87.9
Average total collection				
Dry matter - %	80.7	68.9	61.6	66.7
Energy - %	79.3	67.3	59.9	65.3
Protein - %	76.8	68.1	64.9	73.2
Indicator - Cr_2O_3				
Dry matter - %	69.5	66.4	58.8	59.6
Energy - %	68.0	63.9	57.9	58.3
Protein - %	66.1	66.4	67.8	70.9

collection studies were apparently quite different.

The results from Cr_2O_3 were obtained from all bulls on trial receiving the same percentage Cr_2O_3 in the feed (0.475%) which overcame the problem of varied feed intake by the bulls. The four bulls in each treatment group were used to arrive at the means shown in Table 6. The digestibility of the dry matter and protein showed no significant difference ($P>0.05$) between treatments. The digestion coefficients for energy showed a significant difference ($P<0.01$) between full and restricted feeding. This is indicated by the averages of 66.0% and 58.1% for full and restricted feeding, respectively. The digestion coefficients for energy showed no significant ($P>0.05$) effect due to DES supplementation.

The whole empty body weight gain was determined by measuring the difference between the initial empty body weight and the final empty body weight. A whole empty body weight gain of 84.92 kg water, 21.21 kg fat and 26.39 kg protein was obtained for the full fed bulls. Restricted fed bulls gained 49.56 kg water and 11.25 kg protein and lost 5.22 kg fat (Table 7).

The energy stored in the gain was determined by using 9.377 kcal per gm of fat with a standard deviation of ±0.097 kcal per gm as determined from 13 fat samples. This value compares very well to the values of 9.367 (Blaxter and Rook 1953), and 9.385 (Garrett and Hinman 1969), but is

TABLE 7. - Determination of energy retention following 140 days on feed

Item		Level of feeding	
		Full	Restricted
Initial shrunk weight	- kg	270	270
Initial empty body weight	- kg	256	256
Initial body composition			
Fat	- %	14.4	14.4
Water	- %	61.8	61.8
Protein	- %	19.2	19.2
Weight fat	- kg	37.0	37.0
Weight protein	- kg	49.2	49.1
Weight water	- kg	158.6	158.4
Final shrunk weight	- kg	430	361
Final empty body weight	- kg	395	313
Final body composition			
Fat	- %	14.7	10.1
Water	- %	61.5	66.4
Protein	- %	19.1	19.3
Weight of fat	- kg	58.2	31.8
Weight of protein	- kg	75.6	60.4
Weight of water	- kg	243.5	208.0
Gain in water	- kg	84.9	49.6
Gain in fat	- kg	21.2	-5.2
Gain in protein	- kg	26.4	11.2
Energy gain in fat (Mcal)[1]		198.88	-48.95
Energy gain in protein (Mcal)[2]		137.80	58.75
Total energy gain (Mcal)		336.69	9.80
Daily energy gain (Mcal)		2.40	0.07

[1] Energy level of fat - 9377±97 cal/gm

[2] Energy level of protein - 5222±64 cal/gm

slightly lower than the values of 9.439 and 9.499 given by Franke and Weinger (1955) and Stroud (1961), respectively. The caloric value and standard deviation for the dry fat-free organic matter of the carcass was 5.222 ± 0.064 kcal per gm as determined from 18 samples. This value compares quite well with the values of 5.367 and 5.238 given by Blaxter and Rock (1953) and Paladinas et al., (1964), but is lower than the values of 5.447 (Stroud 1961), and 5.532 (Garrett and Hinman 1969).

A comparative slaughter method was used to measure energy retained in whole empty body gain. The average energy stored as whole empty body gain was 336.69 Mcal or 2.40 Mcal per day and 9.80 Mcal or 0.07 Mcal per day for the full and restricted fed groups, respectively (Table 7). It is shown by the results here that the rate of energy retention by restricted bulls is only 2.9% of that of full fed bulls. However, in Table 3 it is indicated that, for 140 days, the restricted bulls gained at a rate of 59% of the full fed bulls. The results in Table 7 show a marked loss of 5.2 kg fat and a gain of 11.2 kg protein for bulls on restricted feeding. This would seem to indicate that liveweight gain does not relate to empty body energy retention. Digestion trials using Cr_2O_3 were used to determine the digestible energy values for the ration. The metabolizable energy was calculated from digestible energy by using a factor of 0.82 (NAS-NRC, 1970). The total

heat production can be determined from energy retained in gain and ME as shown in Table 8. The total heat values shown in Table 8 includes much useful heat such as heat of basal metabolism and heat of activity as well as the heat increment of the feed. Table 8 also shows heat produced as a percentage of the ME of the ration. The indication here is that animals on restricted feeding use a much higher percentage of their energy intake for maintenance than do animals on full feeding. A similar observation was noted by Lofgreen (1965).

Determination of NE_m

To determine the NE_m it is necessary to know the heat production of an animal at fasting or zero feed intake. The current expression used for the heat production of fasting is 77 $W^{0.75}$, which expresses the value in kcal per day when W is in kg (Lofgreen and Garrett 1968). The weight value for $W^{0.75}$ will be in kg for the remainder of the thesis. Heat production (HP) can be determined indirectly from the energy balance of production (EB) and ME by the equation:

$$HP = ME - EB$$

This calculation is done in Table 8 and is expressed on a metabolic body size ($W^{0.75}$) basis for full and restricted feeding.

Heat production is made up of heat of basal metabolism, heat increment and heat of activity. At zero feed intake the heat increment is zero thus HP is composed of heat of basal metabolism and heat of activity which would be NE_m for the animal. Therefore, if HP is calculated for various

TABLE 8. - Energy use of ration on daily basis

	Level of feeding	
	Full	Restricted
Mean empty body weight (kg) (W)	326	285
Metabolic body size ($W^{0.75}$)	76.7	69.3
Metabolizable energy intake (kcal)	17,640.0	10,086.0
Energy retained (kcal)	2,405.0	70.0
Heat produced (kcal) (HP)	15,235.0	10,016.0
$ME/W^{0.75}$	229.9	145.5
$P/W^{0.75}$	198.9	144.5
Heat as a percent of ME	86.3	99.3

levels of feed intake and plotted, the HP at zero feed intake can be determined by extrapolation. The HP and ME intake for two levels of feeding were determined in this experiment (Table 8).

A comparison of the fasting heat production was made between values published by Lofgreen and Garrett (1968) and data from this study reported in Table 8. The log of HP was plotted against the ME intake and the results are shown in Figure 7 which, when extrapolated to zero feed intake, intercepted at a value of 83 kcal/$W^{0.75}$ for heat production of fasting. This value was obtained by the use of only two points from Table 8, compared to a large number of points used by Lofgreen and Garrett (1968). However, this value compares well with the values of 75 and 77 obtained by Lofgreen (1965) and Lofgreen and Garrett (1968) respectively.

The feed intake required to maintain an animal in energy equilibrium will be the feed required for NE_m and will contain energy equal to HP at zero feed intake. When the energy intake from a ration is equal to the energy of heat production, an animal would be in energy equilibrium.

The energy equilibrium value was determined by using the technique of Lofgreen and Garrett (1968). The regression between a point determined by ME of 229.96 kcal/$W^{0.75}$ and HP of 198.61 kcal/$W^{0.75}$ and a point determined by HP of 77 kcal/$W^{0.75}$ and zero ME intake was obtained as follows:

$$\text{Log HP} = 1.88649 + 0.0017895 \text{ ME}$$

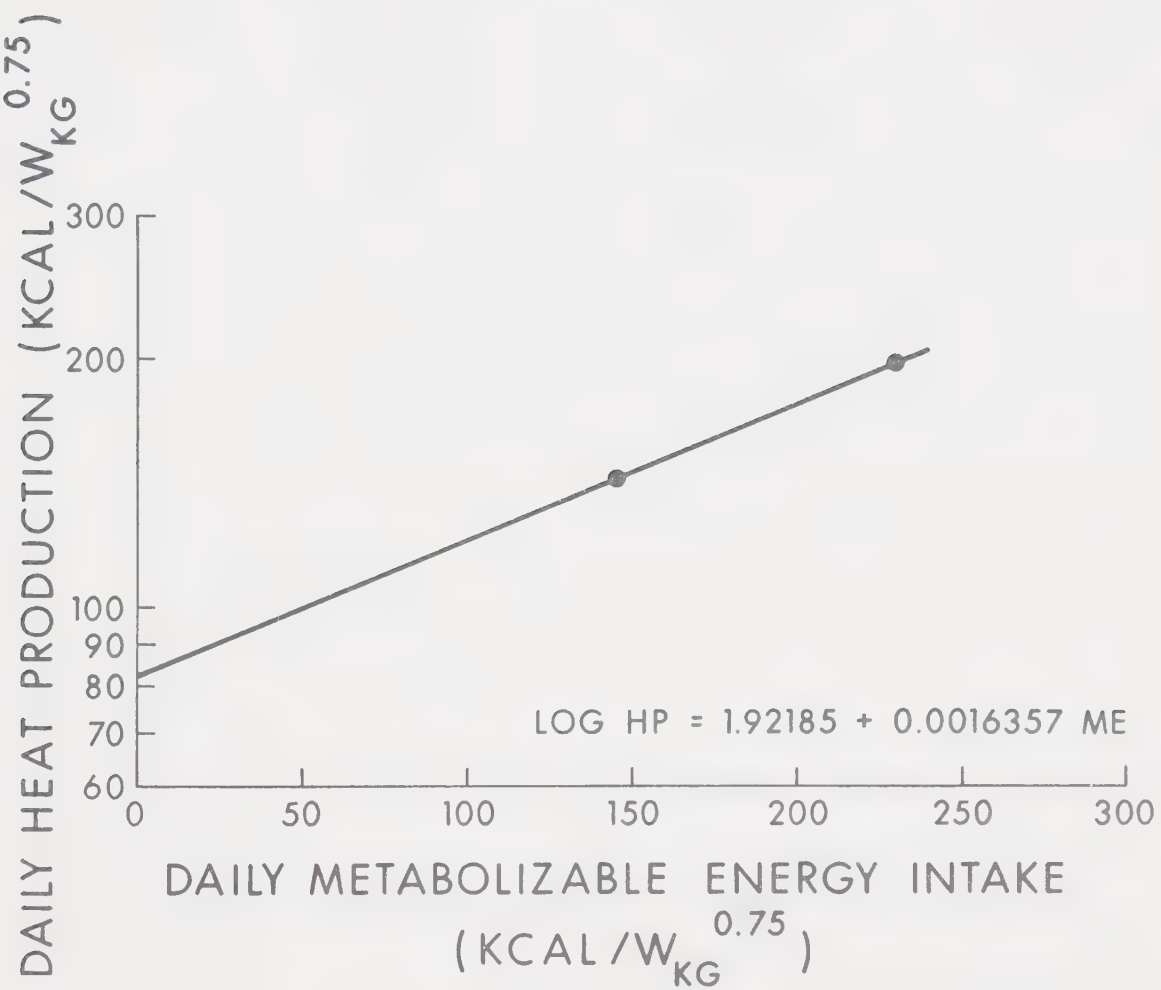

Figure 7. Determination of fasting heat production

and is plotted in Figure 8. From this regression the point of energy equilibrium was determined to be 133.43 kcal/$W^{0.75}$.

NE_m was determined by using the method of calculation for a difference trial (Lofgreen 1965) between the energy equilibrium and fasting of the restricted fed bulls as shown in Table 9. In this case bulls were at energy equilibrium at 9248 kcal ME (133.43 kcal/$W^{0.75}$ x 69.3 $W^{0.75}$) or 4.38 kg (9248 kcal ÷ ME for the ration of 2110 kcal/kg) of dry matter intake. This amount of dry matter intake has a net energy for maintenance equal to the HP at zero feed intake. Therefore, the NE_m is 1.218 Mcal/kg dry matter intake.

Determination of NE_g

The NE_g value of a ration is equal to the energy stored in the body weight gain resulting from consumption of this ration. This has normally been determined by feeding the experimental ration at two levels and measuring the energy deposition brought about by the increase in feed intake of one level of feeding over the other (Lofgreen 1965 and Lofgreen and Garrett 1968). In the case of this ration both levels of feeding were above maintenance because both promoted weight gain. Table 10 illustrates the difference in the feeding. The difference in the feeding level between the full and restricted groups was 0.02703 kg/$W^{0.75}$ dry matter intake. This caused a difference of 30.33 kcal/$W^{0.75}$ to be retained in gain. This gives a NE_g value for the

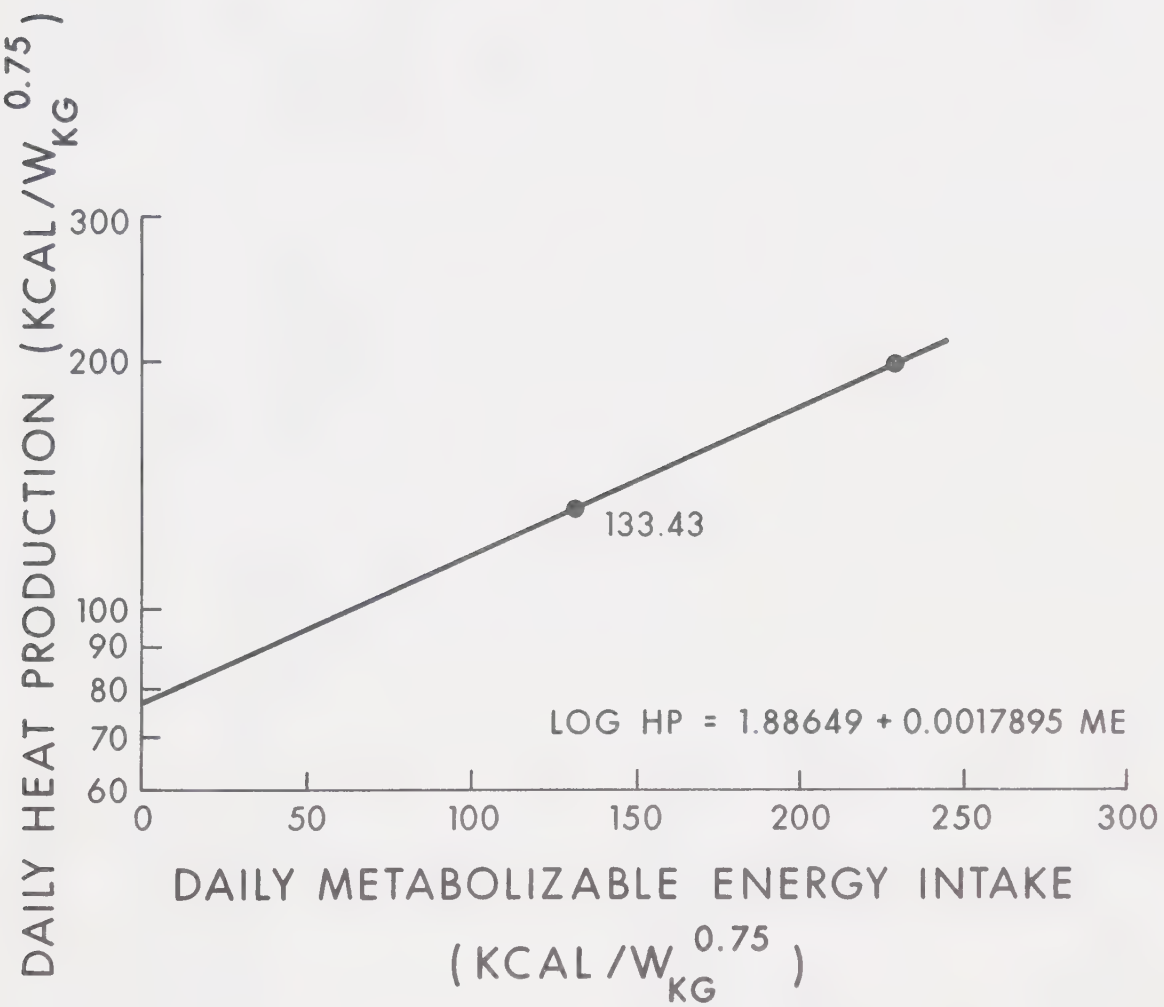

Figure 8. Determination of energy equilibrium

TABLE 9. - Net energy for maintenance by difference trial

Feeding	$W^{0.75}$ kg	Dry matter intake kg	Metabolizable energy intake kcal	Energy gain[1] kcal
Energy equilibrium	69.3	4.38	9248	-
Fasting	69.3	-	-	5336.87
		4.38	9248	5336.87

[1] NE_m of ration is thus 5336.87 kcal in 4.38 kg or 1.218 Mcal/kg

TABLE 10. - Net energy for gain by difference trial

Feeding level	$W^{0.75}$ kg	Dry matter intake kg/$W^{0.75}$	Energy gain[1] kcal/$W^{0.75}$
Full feeding	76.7	0.09599	31.35
Restricted feeding	69.3	0.06896	1.02
		0.02703	30.33

[1] NE_g of the ration is thus 30.33 kcal per 0.02703 kg or 1.122 Mcal/kg

TABLE 11. - Net energy for maintenance and gain for the two levels of feeding

	Full feeding	Restricted feeding
Mean metabolic body size (kg)	76.7	69.3
Energy expended for maintenance* (kcal)	5906.7	5336.9
Energy retained (kcal)	2405	70.5
Total net energy (kcal)	8311.7	5407.4
Total dry matter intake (kg)	7.36	4.78
NE_{m+g} of feed (Mcal/kg)	1.129	1.131

*$77\ W^{0.75}$ kg

ration of 1.122 kcal/kg dry matter intake.

The NE_m was higher than the NE_g in this trial. This relationship is in agreement with and is used by Lofgreen (1965) and Lofgreen and Garrett (1968) to explain the system of determining net energy requirements. Lofgreen (1965) also indicates that the NE_{m+g} should be intermediate to NE_m and NE_g. This would be expected because the animal that was gaining rapidly would be using more feed for NE_g; thus, the NE_{m+g} would tend to approach that of NE_g. Animals on lower levels of feed intake would tend to have higher NE_{m+g} values for the ration because a larger portion of the ration would be used for maintenance. The results for NE_{m+g} for the two levels of feeding are shown in Table 11 to be 1.129 and 1.131 Mcal/kg dry matter intake for the ration for full and restricted feeding, respectively.

There was no difference between the NE_{m+g} for full vs. restricted fed bulls in this experiment. This may be due to the fact that the NE_m and NE_g for the ration used in this experiment were very close together. Lofgreen (1965) obtained a larger difference in feed intake and energy gain for his difference trial than was shown for this experiment. This difference in feed intake and energy gain caused a wider spread between NE_m and NE_g values compared to values reported for this experiment. The calculated NE_m and NE_g values from NAS-NRC (1970) feed composition tables for the ration used in this study were 1.90 and 1.218 Mcal per kg of dry matter, respectively. The determined NE_m and NE_g for this experimental

ration was 1.218 Mcal and 1.122 Mcal per kg of dry matter intake, respectively. The NE_g values determined in this experiment are very close to calculated values using NAS-NRC (1970) feed composition tables. However, NE_m values from this experiment and NAS-NRC (1970) feed composition tables are not as close together as NE_g values. The differences shown in NE_m values may be mainly due to variations in digestibility determination for ME for the restricted feeding group. Some of the difference between calculated values and values derived from this experiment may be a result of animal difference, variations in feed consumption or environment.

SUMMARY AND CONCLUSIONS

The present research project was designed with two levels of feeding to investigate the influence of DES on the performance of feedlot bulls. The project was also used to compare two methods for determining the body composition of bulls. The body composition was used to estimate NE_m and NE_g for the ration. Thirty hybrid bull calves with an average initial liveweight of 270 ± 4.7 kg (mean and standard deviation) were used in this study.

An initial group of six bulls were slaughtered at the start of the experiment. Eight bulls were slaughtered after 56 days on test and the remaining sixteen bulls were slaughtered after 140 days on test. The different slaughter dates provided a wide range in age and body composition for comparison.

A significant linear relationship occurred between the chemical analysis of the carcass and specific gravity method for determination of body composition. These relationships are as follows:

$Y = 10.16 + 0.80\ x \qquad S_{y.x} = 1.14$

$Y = -\ 0.57 + 1.08\ x \qquad S_{y.x} = 1.51$

$Y = -50.41 + 3.64\ x \qquad S_{y.x} = 0.65$

for water, fat and protein respectively. In the above equations x equals specific gravity results for percent composition of the empty body and y equals chemically determined results for composition of the carcass.

The effect of DES at both levels of feeding and for both slaughter periods was nonsignificant ($P>0.05$) for rate of gain, feed efficiency, or the content of fat, protein and water in the body.

The NE_m and NE_g were calculated to be 1.218 Mcal and 1.122 Mcal per kg dry matter intake, respectively. The NE_{m+g} was calculated for the two levels of feeding to be 1.129 Mcal and 1.131 Mcal per kg of dry matter intake for full and restricted feeding, respectively. It should be noted that the NE_m is very dependent on digestibility of energy for the ration for consistent units.

It would appear from this study that the specific gravity method can be used as a quick and accurate determination of body composition for carcasses of young bulls over a large variation in carcass composition.

BIBLIOGRAPHY

Association of Official Agricultural Chemists. 1965 Official Methods of Analysis, ed. 10. Washington, D.C.

Bailey, C. M., C. L. Probert and V. R. Bohman. 1966a. Growth rate, feed utilization and body composition of young bulls and steers. J. Animal Sci. 25:132.

Bailey, C. M., C. L. Probert, P. Richardson, V. R. Bohman and J. Chancerelle. 1966b. Quality factors of the longissimus dorsi of young bulls and steers. J. Animal Sci. 25:504.

Bear, R. S. 1952. Structure of Collagen fibrils. Advances in Protein Chemistry 7:69.

Beeson, W. M. 1969. How beneficial are feed additives. J. Am. Vet Med. Ass. 154:1214.

Bidart, J. B., R. M. Koch and V. H. Arthaud. 1970. Comparative energy use in bulls and steers. J. Animal Sci. 30:1019.

Blaxter, K. L. and J. A. F. Rook. 1953. The heat of combustion of the tissues of cattle in relation to their chemical composition. British J. Nutrition. 7:83.

Cahill, V. R., L. E. Kankle and E. W. Klosterman. 1956. Effect of diethylstilbestrol implantation on carcass composition and the weight of certain endocrine glands of steers and bulls. J. Animal Sci. 15:701.

Clegg, M. T., and F. O. Carroll. 1956. Further studies on the anabolic effect of stilbestrol in cattle as indicated by carcass composition. J. Animal Sci. 15:37.

Clegg, M. T. and F. O. Carroll. 1957. A comparison of the method of administration of stilbestrol on growth and carcass characteristics of beef steers. J. Animal Sci. 16:662.

Crampton, E. W., L. E. Lloyd and V. C. MacKay. 1957. The caloric value of TDN. J. Animal Sci. 16:541.

Dinusson, W. E., F. N. Andrews, and W. N. Beeson. 1950. The effects of stilbestrol, testosterone, thyroid alteration and spaying on growth and fattening of beef heifers. J. Animal Sci. 9:321.

Flatt, W. P. 1965. Energy values of feeds. How should they be expressed. Proceeding Eighteenth Washington Animal Nutrition Conference.

Franke, E. R. and J. H. Weniger. 1955. Quoted by Garrett and Hinman. 1969. Neue Untersuchungen uberden Ularmwert von Fleisch und. Fett verschiedener Nutztierarten. Archiv. Tierernahrung 5:142.

Garrett, W. N. and N. Hinman. 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. J. Animal Sci. 28:1.

Garrett, W. N., J. H. Meyer and G. P. Lofgreen. 1959. The comparative energy requirements of sheep and cattle for maintenance and gain. J. Animal Sci. 18:528.

Hedrick, H. B., G. B. Thompson and G. F. Krause. 1969. Comparison of feedlot performance and carcass characteristics of half-sib bulls, steers and heifers. J. Animal Sci. 29:681.

Hill, F. W. and D. L. Anderson. 1958. Comparison of metabolizable energy and productive energy determinations with growing chicks. J. Nutrition. 64:587.

Hoogendoorn, A. L. and C. M. Grieve. 1969. Chromic oxide in digestibility studies with lactating dairy cows. Can. J. Animal Sci. 49:383.

Kraybill, H. F., H. L. Bitter and O. C. Hankins. 1952. Body composition of cattle II. Determination of fat and water content from measurement of body specific gravity. J. Appl. Physiol. 4:575.

Lofgreen, G. P. 1963a. Quoted by Lofgreen and Garrett. 1968. Net energy of feedstuffs and their use in cattle feeding. Arizona Cattle Feeders Rpt., May 2, 1963.

Lofgreen, G. P. 1963b. Quoted by Lofgreen and Garrett, 1968. Net energy - the new way to reckon rations. West. Livestock J. 41:40.

Lofgreen, G. P. 1963c. Quoted by Lofgreen and Garrett, 1968. Nutrition Symposium. Some aspects of energy measurement in ruminant nutrition. Proc. Semi-Annual meeting A.F.M.A. Nutr. Comm., Dec. 2-3, 1963:18.

Lofgreen, G. P. and K. K. Otagaki. 1960. The net energy of blackstrap molasses for fattening steers as determined by a comparative slaughter technique. J. Animal. Sci. 19:392.

Lofgreen, G. P., J. L. Hull and K. K. Otagaki. 1962. Estimation of empty body weight of beef cattle. J. Animal Sci. 21:20.

Lofgreen, G. P. 1965. A comparative slaughter technique for determining net energy values with beef cattle. 3rd Symp. on Energy Metabolism. K. L. Blaxter (ed). Academic Press Inc., London.

Lofgreen, G. P. and W. N. Garrett. 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. J. Animal Sci. 27:793.

Maynard, L. A. and J. K. Loosli, 1969. Animal Nutrition. McGraw-Hill, Toronto.

Meyer, J. H., G. P. Lofgreen, and W. M. Garrett. 1960. A proposed method for removing sources of error in beef cattle feeding experiments. J. Animal Sci. 19:1123.

Mukhoty, H. M. 1969. M. Sc. Thesis. University of Alberta, Edmonton, Alberta.

National Academy of Sciences - National Research Council (NAS-NRC). 1970. Nutrient Requirements of Domestic Animals. No. 4. Nutrient Requirements of Beef Cattle. 7th revised ed. Washington, D. C.

Nygaard, L. J., H. O. Radloff and M. L. Riley. 1971. Holstein bulls and steers for meat production. Proceedings, Western Section American Society of Animal Science. 22:261.

Paladinas, O. L., J. T. Reid, A. Bensadoun and B. D. H. Van Niekerk. 1964. Heat of combustion values of the protein and fat in the body and wool of sheep. J. Nutrition. 82:145.

Rathbun, E. and N. Pace. 1945. The determination of total body fat by means of the body specific gravity. J. Biol. Chem. 158:667.

Reid, J. T., G. H. Wellington and H. O. Dunn. 1955. Some relationships among the major chemical components of the bovine body and their application to nutritional investigations. J. Dairy Sci. 38:1344.

Steel, R. G. O. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, Toronto.

Stroud, J. W. 1961. Quoted by Garrett and Hinman. 1969. Heat of combustion values of the protein and fat in body and wool of sheep. J. Nutr. 82:154.

Van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assn. of Official Agr. Chem. 46:829.